CitiPower	**ELECTRICITY NETWORKS** **Asset Strategy and Performance** **Functional Scope**	Powercor Australia

Functional Scope Created	**3 August 2017**	**By**	Frank Argus		
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Project Title	Bendigo Terminal (BETS) REFCL Installation				
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Related Scopes					
Project Engineer					
System Planning Engineer	Frank Argus				
Protection and Control Engineer	Brodie Stephenson				
Plant and Stations Engineer					
Asset Strategy Engineer					
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Version	Date	Changes	Responsible Officer
1.0	3/08/2017	Original	F. Argus
1.1	9/08/2017	Added secondary requirements	B. Stephenson

1 Project overview

This project scope covers the migration of the Bendigo Terminal Station (**BETS**) system to a resonant earthed network. Migration to a resonant network requires the installation and operation of a ground fault neutraliser (**GFN**). This changes the electrical operating characteristics of a zone substation and its distribution network as follows:

- full voltage displacement occurs on the system for operation of the GFN
- this significantly stresses equipment on the system and may lead to failure
- this equipment has been identified and included in this scope for replacement as part of the GFN installation
- other limitations will dictate part of the operational protocols that will be developed by Electricity Networks.

The GFN provides potential benefits to single-phase-to-ground faults on the 22kV three phase system. It provides no benefit on the following:

- the 12.7kV Single Wire Return System (**SWER**)
- the 66kV sub-transmission system
- the low voltage (**LV**) system.

1.1 Background

The Victorian Government has introduced changes to the Bushfire Mitigation Regulations that require distribution businesses with high voltage (**HV**) overhead assets in high bushfire consequence areas to meet new performance standards for detection and limiting of arc fault energy. These standards can only be achieved using rapid earth fault current limiters (**REFCLs**).

A REFCL is a network protection device, normally installed in zone substations that significantly reduce the arc fault energy generated during a phase to ground fault. The reduction in arc fault energy can be so effective that earth fault fire ignition on 22kV three phase networks is almost eliminated.

The Bushfire Mitigation Regulations mandate that REFCLs must provide the required capacity—required capacity means, in the event of a phase-to-ground fault on a polyphase electric line, the ability:

- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for high impedance faults to 250 volts within 2 seconds
- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for low impedance faults to:
  - 1900 volts within 85 milliseconds
  - 750 volts within 500 milliseconds
  - 250 volts within 2 seconds
- during diagnostic tests for high impedance faults, to limit:
  - fault current to 0.5 amps or less
  - the thermal energy on the electric line to a maximum I^2t value of 0.10

  where:

- high impedance faults means a resistance value in ohms that is equal to twice the nominal phase-to-ground network voltage in volts
- I^2t means a measure of the thermal energy associated with the current flow, where I is the current flow in amps and t is the duration of current flow in seconds

- low impedance faults means a resistance value in ohms that is equal to the nominal phase-to-ground network voltage in volts divided by 31.75
- polyphase electric line means an electric line comprised of more than one phase of electricity with a nominal voltage between 1 kV and 22 kV.

1.2 Bendigo Terminal Station

Bendigo Terminal Station (**BETS**) is located in central Victoria and is owned by AusNet Services. BETS provides 66kV and 22kV points of supply to Powercor though separate transformers. The BETS 22kV supply is from two transformers and Powercor owns eight 22kV feeders with the point of supply at the feeder CB bus side isolators.

The transformers are YNd1 vector group and the 22kV earth is through a Neutral Earthing Compensator (**NEC**) on the 22kV side of each transformer. To enable the installation of a REFCL at BETS22, AusNet Services will provide a connection point to each of the NEC's neutral and jointly operable earthing switches via a separate scope of works. Connection points for two Powercor inverter supply transformers will also be provided by AusNet Services.

Due to fault level limitations the 22kV bus tie CB operates normally open with the two 22kV feeder busses each normally supplied by a single transformer.

Table 1 BETS: existing characteristics (zone substation)

Zone substation	Volume
Feeders	8
Zone substation transformers	2
22kV buses	2
Capacitor banks	0
Station service transformers	2
22kV circuit breakers (switching configuration)	3 (AusNet owned, fully switched)

Table 2 BETS: existing characteristics (network)

Network	Volume
Total route length (km)	742
Underground cable length (km)	37
Overhead line length (km)	706
Underground network (%)	5
Overhead single phase	227
Estimated network capacitance (A)	148

Network	Volume
Distribution transformers	1767
HV regulator sites	5
Fuses	1980
ACRs	9
Surge arrestor sites	1,239
HV customers	4

2 ZSS requirements

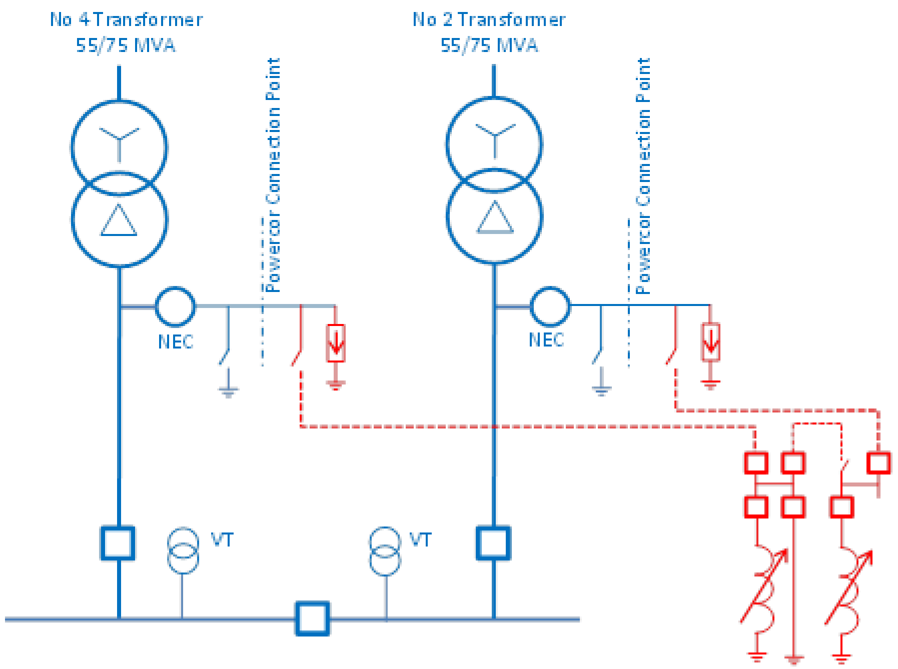
This functional scope sets out the BETS zone substation requirements, including the following:

- establish ASC bunds
- install two (2) Swedish Neutral GFN Arc Suppression Coils
- installation of a neutral bus and earthing system connecting to the Powercor connection points on the 22kV transformer NEC neutrals
  - installation of two (2) Neutral Bus Systems
    - one (1) Type A and one (1) Type B2 (specification ZD081)
    - terminations on to the Powercor connection points at the NEC neutrals
    - ASC terminations
    - transformer terminations
  - installation of 19kV surge arresters at the Powercor connection points on the NEC neutrals
- install two (2) inverter supply transformers using a 500kVA kiosk transformer for each
- install a new AC distribution board with auto-changeover scheme and install cabling from the new inverter supply transformers and cabling to the inverters
- replace all Powercor owned station surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability
- provide settings for the 22kV bus protection schemes for the integration of the REFCL
- development and installation of station earth fault management control relay
  - adoption of existing MEF function
  - neutral voltage supervision
  - neutral bus CB management functions
- upgrade eight (8) SEL-351S 22kV Feeder Protection Relays to IEC-61850 compatible units
- install and commission GFN control and RCC inverter cubicles
- install new Elspec Power Quality Meter
- modification of existing substations communications network configuration
  - install new RSG 2100 Ethernet switch
  - install two (2) new Fortigate 60 firewall units
- extend station yard and earth grid as required to accommodate ASC
- install weather station.

2.1 Primary plant requirements

The works associated with the installation of the BETS22 ASC is summarised in the following single line diagram:

Figure 1 BETS neutral diagram



2.1.1 Arc suppression coil

Install 2 off Swedish Neutral - Ground Fault Neutraliser’s Arc Suppression Coil (**ASC**) component. The arc suppression coil is a paper wound copper coil wrapped around a solid iron core and immersed in oil. This arc suppression coil is of fixed reluctance but contains an array of capacitors in parallel that are switch as part of the tuning process of the coil. The coil also features an LV winding for coupling of these capacitors and the Residual Current Compensator.

Primary neutral and earth connections are via elbows.

As oil filled device, it shall be installed in a bunded area in accordance with current standards. The total volume of oil will be made available once the coil size has been confirmed.

The GFN ASC’s shall be installed vacant space to the west of the 22kV bus, this will require modification of the existing fence at BETS:

- install Ground Fault Neutraliser comprising of 2x 200A ASC and residual current compensation modules with maximum available tuning steps onto the provided pad mount within a newly established bunded area
- the footing of the ASC shall reside on the installed 150mm steel beams fixed to the concrete pad
- install cable connections to and from the Neutral System.

2.1.2 Zone substation surge arrestors

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase’s subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation:

- replace all sub-standard zone substation surge arresters with a station class 22kV continuous voltage arrestor
- install station class 19kV surge arresters across the transformer neutrals.

2.1.3 Inverter supply transformers

AusNet Services will provide a point of connection from the No.2 22kV bus via a set of 22kV isolators and a point of connection from the No.4 22kV bus via a set of 22kV isolators to enable Powercor to install two 22000/433 V inverter supply transformers.

Install a new 500kVA 22kV No. 2 inverter supply kiosk transformer and a new 500kVA 22kV No. 4 inverter supply kiosk transformer at a site to be chosen in the BETS 22kV yard.

- Install HV fuses on the on the Powercor side of the No. 2 bus Inverter Supply connection point
- Connect the No. 2 Inverter Supply transformer to the Powercor connection point from the No.2 22kV bus via the HV fuses
- Install HV fuses on the on the Powercor side of the No. 4 bus Inverter Supply connection point
- Connect the No. 4 Inverter Supply transformer to the Powercor connection point from the No.4 22kV bus via the HV fuses.
- Connect to AC changeover board.

2.1.4 Neutral system arrangement

Two (2) new kiosk type ground mounted Neutral Bus modules shall be installed alongside the ASCs. The neutral bus module comprises of circuit breakers or isolation switches to facilitate selection of transformer NEC neutral earthing while the ASC is out of service and as independent isolation of transformer NEC neutrals in case of an internal fault.

The purpose of this arrangement is to provide a simple switching configuration that offers the following combinations within one kit:

- solid grounding
- ASC in service (solid ground CB open)
- Independently isolating each transformer NEC neutral.

No.2 Neutral Bus

The No. 2 Neutral Bus will be a Type B2 module (refer specification ZD081). This shall consist of two (2) circuit breakers, an isolation switch and a bus VT.

The two CBs shall be arranged as follows:

- transformer No. 2 NEC neutral
- ASC2

The isolation switch shall be arranged as follows:

- neutral bus tie to No. 4 neutral bus.

No. 4 neutral bus

The No. 4 Neutral Bus will be a Type A module (refer specification ZD081). This shall consist of four (4) circuit breakers and a bus VT. The four CBs shall be arranged as follows:

- transformer No. 4 NEC neutral
- ASC4
- solid ground connection

- neutral bus tie to No. 2 neutral bus.

Neutral bus connections

The connection to the neutral bus module shall be via elbow connections. Four (4) elbows are required at one module and three (3) at the other for:

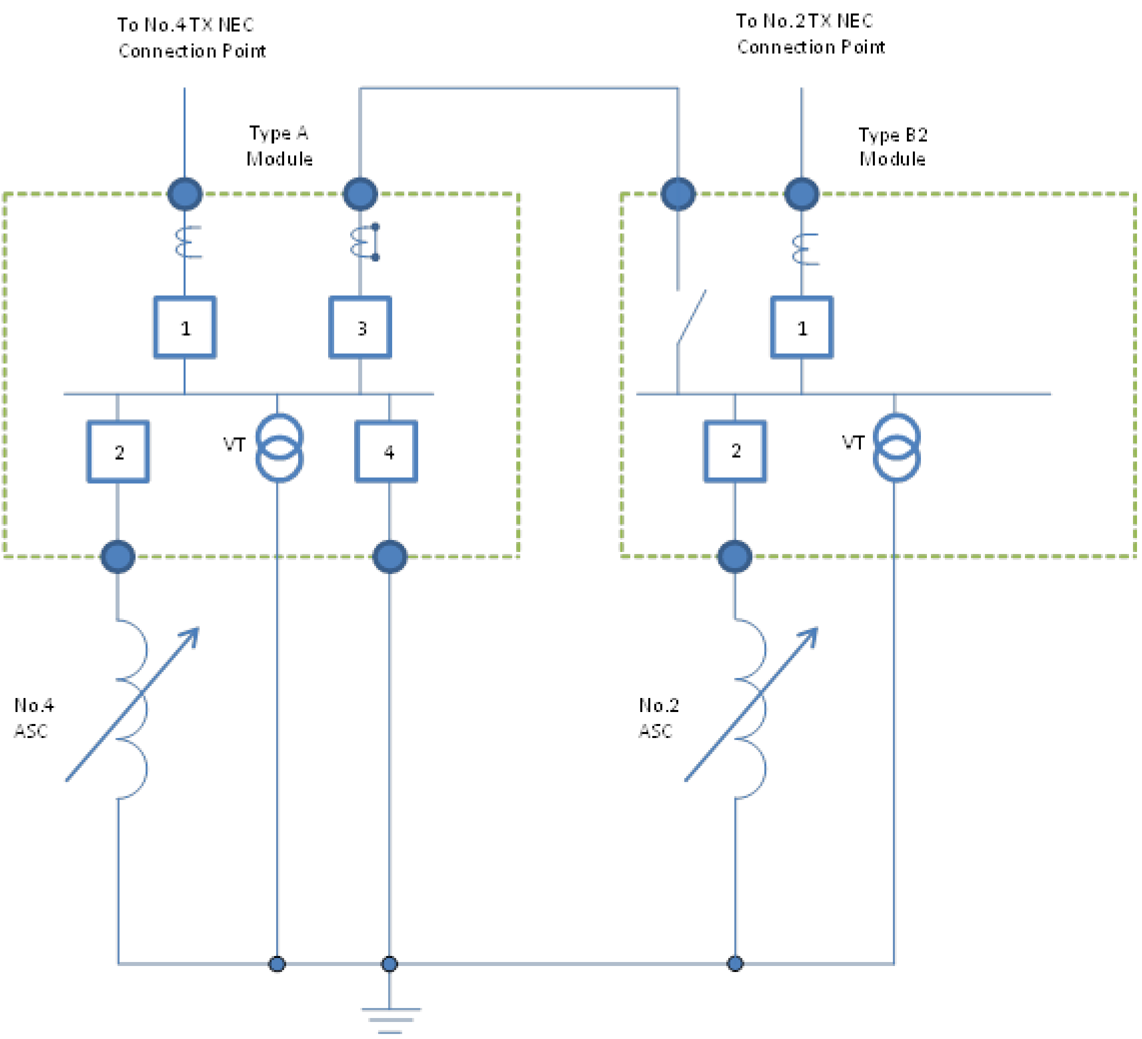
- transformer NEC Neutral connection (2 transformer NECs)
- neutral bus tie
- ASC connection (2 ASCs)
- solid ground connection

Refer to figure 2 for connections.

Neutral voltage transformer

A neutral VT shall be included in each of the Neutral Bus modules. The neutral VT shall be 0.5M 1P at 15VA.

Figure 2 Neutral Bus and ASC Connections



2.1.5 22kV bus voltage transformers

The 22kV bus VT's belong to AusNet Services, and the nameplates show a 1.9 x voltage rating for 8 hours which is appropriate for REFCL installations.

2.1.6 Transformer Earthing

The two (2) 220/22kV transformers in service at BETS22 are star/delta connected with NECs installed on the 22kV side to allow the neutral of the NEC star point to be solidly earthed. AusNet are installing a jointly operated earth switch and a Powercor point of connection to each NEC neutral.

A neutral earthing arrangement connected to and linking the Powercor connection points at each transformer NEC neutral shall be installed with the following parallel connections as shown in Figure 1:

- Surge diverter rated at 19kV (must be able to withstand 12.7kV neutral voltage under earth fault conditions)
- HV single phase cable connection to a Neutral Bus module from the Powercor point of connection at the NEC neutral via an isolation switch at the Powercor point of connection end
- Neutral bus module connection via circuit breaker at the neutral bus module.

The Powercor point of connection at each NEC neutral shall be connected to a Neutral Bus module using a HV insulted single phase cable installed underground from the Powercor point of connection to the HV CB (via the elbow connections) on the neutral bus modules (RMU).

2.1.7 22kV feeder CTs

The ability to detect 25.4 kΩ faults requires a high level of accuracy in measurement to optimise network balancing. Perform diagnostic testing to confirm 25.4 kΩ faults while releasing less than 0.10 I^2T, as mandated by Regulations, also requires very accurate current measurements.

The existing feeder CT specifications are outlined below.

Table 3 Feeder CT information

Feeder	CT Spec	Required Action
BET001	5P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
BET002	5P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
BET003	0.2PX100 R0.15	Suitable for sensitivity requirements
BET004	0.2PX100 R0.15	Suitable for sensitivity requirements
BET005	0.2PL100 R0.2	Suitable for sensitivity requirements
BET006	0.2PL100 R0.2	Suitable for sensitivity requirements
BET007	0.2PX100 R0.15	Suitable for sensitivity requirements
BET008	0.2PX100 R0.15	Suitable for sensitivity requirements

At BETS zone substation, two (2) feeder CT's need to be installed and will require associated modifications of the 22kV bus structures and civil works to facilitate their installation. An alternative option to avoid modification to bus structures was considered, this option involved complete replacement of 22kV circuit breakers and was found to be a more expensive solution.

- Review fault levels, wiring length and relay burdens and define required specification to procure PX class CTs
  - note: factory acceptance of CTs requires non-standard testing to confirm accuracy of zero sequence measurement through full range of load
- Relocation of existing bus structure to facilitate the installation of a new 22kV structure in each feeder bay that requires new CTs
- Installation of new 22kV CT mounting structure in each feeder bay that requires new CTs
- Install CTs and modify secondary relay settings for new CT ratio's and test CT polarity.

2.1.8 Earth Grid Resistance

Experience from our REFCL trial substations and Camperdown zone substation has shown that the earth grid impedance in multiple REFCL substations negatively impacts on the ability to achieve 25.4 kΩ fault detection. In our desired range of network size (less than 108A) an earth grid impedance of 0.45 Ω will result in a neutral voltage developed in the unfaulted bus up to 1.5kV which is greater than the fault detection threshold for required capacity.

At BETS zone substation, the following works are required to reduce the earth grid impedance to below 0.2 Ω:

- Site survey, earth grid and soil resistivity testing
- Detailed analysis and modelling of earth grid and soil conditions
- Design of earth grid modification works
- Additional earth stakes and earth grid installation
- Retesting of earth grid.

2.2 Civil works requirement

For neutral systems

- Install concrete foundation pad for neutral system modules
- Install neutral cable conduit, control cable conduit and provision for solid earth grid connections
- Install neutral cable conduits from transformers to neutral bus
- Install neutral cable conduits from NER to neutral bus
- Install conduits for secondary circuits

For ASC:

- Install neutral cable conduit, control cable conduits and solid earth grid connections
- Pour concrete foundation
- Install steel beam, 150mm high at a width designed to accommodate the placement of the GFN arc suppression coil
- Install bunding to EPA requirements.

For inverter supplies:

- Install concrete foundation pad for two (2) 500kVA kiosk transformers.

2.3 Secondary works

The following outlines the Protection and Control requirements.

All secondary drawings shall be in the wiring schematic format consistent with the existing suite of drawings for the station.

2.3.1 Protection Schemes

Master Earth Fault, Neutral Overvoltage & Neutral Bus Management

- Retire existing 2C137 Master Earth Fault Relay
- Install new F35 neutral bus management relay
  - CB management functions of the six (6) Neutral Bus Switchgear Circuit Breakers
  - Master Earth Fault
  - back up neutral overvoltage
  - integration with Station Earth Fault Management relay via IEC 61850 GOOSE
  - connection of Bus VT's (RWB), MEF CTs & and Neutral VTs

Station Earth Fault Management

- Install SEL-451 Station Earth Fault Management (SEFM) Relay
  - all SEFM functions are via IEC 61850 and require only Ethernet connection to the Powercor Station Sub-LAN network.

22kV Feeder Protection

- All SEL-351S shall be upgraded to firmware version R516 with setting version Z106
- IEC 61850 option shall be applied with the upgrade
- New settings created to reflect the current version of the SEL-351S feeder management relay standard application manual.

22kV CB Management

- Transformer and bus tie CB's are owned by AusNet Services. No associated works are required
- Refer to section 2.3.16 for interface requirements.

Transformer Differential Protection

- Transformer and bus tie CBs are owned by AusNet Services. No associated works are required
- Refer to section 2.3.16 for interface requirements

22kV Bus Protection

- Bus protection schemes are owned by AusNet Services. No associated works are required
- Refer to section 2.3.16 for interface requirements

22kV Bus Distance Protections

- 22kV bus distance protection schemes are owned by AusNet Services'. No associated works are required
- Refer to section 2.3.16 for interface requirements.

AusNet Services Secondary Interface

- The two (2) REFCL systems require current sources from AusNet Services' equipment to provide secondary quantities for GFN Earth Fault protection of the following zones:
  - No.2 transformer and Neutral Earthing Compensator
  - No.2 22kV bus
  - No.4 transformer and Neutral Earthing Compensator

Control Schemes

22kV Voltage Control

- Confirm with AusNet Services that the 22kV VRR operates of phase-to-phase quantities and will be unaffected by REFCL operation

22kV UV/OV Supervision

- Confirm with AusNet Services that the 22kV UV/OV Supervision relay operates of phase-to-phase quantities and will be unaffected by REFCL operation
- Confirm with AusNet Services that the 22kV VRR operates of phase-to-phase quantities and will be unaffected by REFCL operation

2.3.2 Ground Fault Neutraliser

Control Cubicle

- Install two (2) x GFN Control cubicles adjacent to the existing Powercor 22kV feeder protection schemes
  - 800w x 2300h x 665d
  - freestanding rear entry cubicles
- Interface requisite secondary circuits
  - AC & DC Supplies
  - 22kV feeder I_N residual current secondary circuits
  - 22kV bus Voltage supplies
  - Ethernet and fibre optic connections

Inverter

- Installation of two (2) Swedish Neutral 320kVA RCC inverter systems for each of the No.2 and No.4 22kV bus schemes
  - inverters shall be co-located in a single inverter hut installed within the BETS yard. Location to be determined in conjunction with AusNet Services
- Supply and install requisite power, control and communication cabling as per the GFN cable plan
  - 240V 6A AC control supplies
  - 415V 500 A inverter power supplies
  - ASC and grid balancing cabinet interconnection cables
  - control and optic fibre cable from GFN control cabinets

Grid Balancing Units

- Installation of two (2) Swedish Neutral grid balancing systems for each of the No.2 and No.4 22kV bus schemes
- Grid Balancing systems are located adjacent to the RCC Inverter cubicle for each of the two (2) schemes

2.3.3 VT supplies

- Red, White & Blue 22kV VT supplies shall be made available to the No.2 and No.4 GFN control cabinets from the No.2 and No.4 22kV Bus VT's respectively

2.3.4 Protection settings

- Protection settings shall be reviewed for coordination with field devices and supporting information attached in RESIS complete with Issued Setting File and Setting Summary Document

2.3.5 Protection relay configurations

Powercor Network Protection and Control will make standard relay configuration files available to the Service Provider where appropriate. Given the nature of this project, the service provider must expect that this project will have non-standard requirements.

2.3.6 Metering requirements

Metering Schemes

- The existing arrangement for 22kV power quality metering shall be retained
- Installation of an ELSPEC G5 Digital Fault Recorder is required for the REFCL
- Two (2) x Eight (8) channel voltage/current cards shall be installed
  - Card 1 – No.2 22kV Bus
    - Red, White and Blue phase currents
    - Red, White and Blue voltages from the REFCL compatible bus VT
    - No.2 ASC current
    - No.2 neutral bus voltage
  - Card 2 – No.4 22kV Bus
    - Red, White and Blue phase currents
    - Red, White and Blue voltages from the REFCL compatible bus VT
    - No.4 ASC current
    - No.4 neutral bus voltage

2.3.7 Communications Requirements

Refer to Appendices 4.4 for an overview of the Ethernet communications architecture.

Ethernet Connectivity

- Devices shall connect to the BETS station sub-LAN in accordance with CP_PAL_61850_001 - Implementation Policy. The Type 1 arrangement as described by the policy shall suffice.

Engineering Access

Engineering access shall be made available using the Ethernet infrastructure.

Time Stamping

- A Tekron TCG01-E shall be installed to provide time stamping services
  - all devices shall synchronise time via NTP where possible
  - non NTP devices may connected using IRIG-b

2.3.8 415/240 AC supplies

- GFN RCC supplies shall be taken from a new Auto Changeover board supplied from the two (2) new 500kVA No.2 and No.4 Station Service transformers
- ASC 240V supplies shall be taken from the same board
- 240V cubicle supply for the GFN control cubicle may come from general light and power supplies within the BETS control room.

2.3.9 DC Supplies

- New equipment shall be supplied from existing DC supplies
- AusNet Services shall be consulted for additional capacity requirements

2.3.10 Station Design

All secondary drawings shall be in the wiring schematic format consistent with the existing suite of drawings for the station. Agreement with AusNet Services for the design interface shall be received in writing before commencing detailed design.

As a minimum the secondary design documentation shall include:

- 22kV station schematic diagram
- Protection, control, instrumentation and alarm data schedules
- Control room layout and elevation of cubicles
- Cubicle layouts
- Wiring schematics/diagrams for individual protection, control and metering schemes
- DC supply schematics
- Remote control equipment and associated data schedules
- Labelling for cubicles and all slide link terminals
- Manufacturer and interface drawings for the Ground Fault Neutraliser equipment

The latest modular design concepts shall be used as far as practical for this project.

2.3.11 Powercor control centre SCADA works

- BETS 22kV pages shall be modified to include;
  - neutral bus arrangement, controls, status and alarms
  - GFN (REFCL) control, status and alarm pages
  - additional alarms for feeder protection relays
- Capacitive Balancing Substations
  - control Pages for all three (3) phase and single (1) phase balancing systems

A new series of Control System Pages shall be created for the GFN interface. Consultation between SCADA, Operations and Network Protection and Control is required to establish these pages.

2.3.12 Fibre Optic Cable

Fibre optic patch leads are required for Zone Substation Sub-LAN Ethernet communications.

- All Fibre Optic Ethernet cable shall be of type OM3
- OM1 may be used in cases where 62.5/125µm is required
  - GFN to RCC communication

2.3.13 Radio

No radio communications are required.

2.3.14 Weather Station

A weather station is to be installed in order to provide monitoring of temperature, solar radiation, wind speed and humidity in the area. This provides an indication of REFCL sensitivity as it will fluctuate as the network damping (resistive leakage to earth) will vary with weather conditions. Care is to be taken when earthing the weather station to ensure there is no risk of damage to the control room from lightning strikes.

2.3.15 Building and Property Considerations

Yard lighting

Switch yard lighting shall be reviewed to ensure adequate coverage of the ASC, Neutral System.

Fire suppression

The ASC winding is immersed in oil. A review of its design and the amount of contained oil is required to determine if any fire suppression assets are required.

2.3.16 AusNet Services – interface requirements

REFCL installation requires an interface with AusNet Services secondary systems such that the integration of protection and control schemes can be established.

A clearly defined interface terminal strip shall be established within the Powercor cubicles for such connection.

The interface shall be clearly labelled with the following grouping:

- CT Circuits
- Status and control signals **from** AusNet Services
- Status and control signals **to** AusNet Services

All control and status signals shall be initiated by clean contacts**.**

CT secondary circuits

- No.4 Transformer 22kV CB
  - access to the residual (I_N) quantity of the No.4 transformer 22kV CB currently part of the No.4 transformer 220/22kV differential circuit
  - this circuit will be summated on the Powercor side of the interface with the No.4 NEC CT within the No.4 neutral bus to provide the No.4 transformer/NEC earth fault protection zone into the REFCL controller
- No.2 Transformer 22kV CB

- access to the residual (I_N) quantity of the No.2 transformer 22kV CB currently part of the No.4 transformer 220/22kV differential circuit
- this circuit will be summated on the Powercor side of the interface with the No.2 NEC CT within the No.2 neutral bus to provide the No.2 transformer/NEC earth fault protection zone into the REFCL controller

- No.4 22kV Bus Zone
  - access to the summated residual (I_N) quantity of the No.4 22kV bus zone overcurrent circuit
  - this circuit will provide the No.4 22kV bus earth fault protection zone into the REFCL controller
- No.2 22kV Bus Zone
  - access to the summated residual (I_N) quantity of the No.2 22kV bus zone overcurrent circuit
  - this circuit will provide the No.2 22kV bus earth fault protection zone into the REFCL controller

Control and Status Signals to AusNet Services

- CB trip signals
  - No.4 transformer zone
  - No.2 transformer zone
  - No.4 22kV bus zone
  - No.2 22kV bus zone
- No.4 neutral bus CB status
  - No.4 transformer/NEC neutral CB status
  - direct ground neutral CB status
  - No.4 ASC neutral CB status
  - No.4-2 neutral bus tie neutral CB status
- No.2 neutral bus CB status
  - No.2 transformer/NEC neutral CB status
  - direct ground neutral CB status
  - No.2 ASC neutral CB status
- BUEF inhibit signal
- Back up neutral over-voltage protection OFF/ON status

Control and Status Signals from AusNet Services

- Trip Received Signal
  - No.4 Transformer Zone
  - No.2 Transformer Zone
  - No.4 22kV Bus Zone
  - No.2 22kV Bus Zone
- BUEF status
- No.4-2 22kV Bus Status

- No.2 22kV transformer CB status
- No.4 22kV transformer CB status
- NOAC scheme
  - auto close operate signal

3 22 kV distribution feeder requirements

3.1 Surge diverters and insulation limitations

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase's subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation, replace approximately 3,190 surge diverters across the 22kV three phase and single phase system.

This covers all feeders ex BETS as well as surge arrestors beyond inter-station open points shall also be upgraded to permit transfer of loads with the GFN in service.

The replacement diverters should be of 22kV continuous rating with a 10 hour 24kV TOV rating such as the ABB POLIM D 22kV arresters.

CitiPower and Powercor previous standard surge diverters were the ABB MWK 20 and POLIM D 20 arresters.

These, and all previous types except Bowthorpe 'Type A' arresters do not meet the overvoltage requirement needed for use with a GFN and therefore the higher rated arresters are required.

These surge diverters will be a new standard, applicable to distribution systems with a GFN installed.

3.2 Distribution transformers

Operation of the GFN displaces the neutral voltage of the entire 22kV system from the bus to the outer extremities of the feeders. This is different from an NER arrangement, when displacement is at its highest for a fault on the 22kV bus, and decreases for faults occurring down the feeders.

During GFN commissioning, voltage offset testing will simulate the voltage displacement that will occur for a single-phase-to-ground fault (22kV phase-to-ground).

1. Some distribution transformers may not be in a condition to withstand the overvoltage and will subsequently fail during the voltage offset testing
2. Some distribution transformers may fail following repeated subjection to sustained over-voltages caused post commissioning due to normal operation of the GFN

At this time, experience from network resilience (voltage stress) testing at GSB and WND does not support a proactive replacement of any distribution transformers.

3.3 Line insulators

As is the case above for distribution transformers, line insulators are also susceptible to premature failure caused by the repetitive over-voltage stresses.

At this time, experience from the network resilience testing does not support a proactive replacement of any line insulators.

3.4 Line regulators

Single phase open-delta-connected Cooper regulators displace the system neutral voltage by regulating line-line voltages on two phases as opposed to three.

Closed-delta independent regulator control schemes tap each regulator independently, a similar displacement to the neutral voltage occurs, as per the open-delta mode.

All regulator works shall be compliant with current CitiPower and Powercor standards for 22kV regulators.

The BETS distribution network contains five 22kV regulating systems:

Table 4 BETS regulating systems

Feeder	Name	Manufacturer	Phasing	Issue
BET001	MARONG SOUTH P11A REG	COOPER	RWB	Open delta with independent voltage control.
BET001	NEWBRIDGE P30 & P30A REG	COOPER	RWB	Open delta with independent voltage control.
BET004	LOCKWOOD STH P127 REG	Wilson Elec	RWB	No Issue
BET005	LONGLEA P131 REG	COOPER	RWB	Open delta with independent voltage control.
BET005	REDESDALE P3 REG	Wilson Elec	RWB	No Issue

The following regulators require modification in order to meet the requirements for installing the GFN.

3.4.1 Marong South P11A Regulator

Marong South P11A regulator is an open delta connected regulator; this artificially moves the neutral point of the line beyond it. This must be either replaced with a 3-phase ground type regulator, or a third single phase regulator installed on a neighbouring pole and a control scheme installed to ensure that all 3 phases tap in unison.

3.4.2 Newbridge P30 & P30A Regulator

Newbridge P30 & P30A regulator is an open delta connected regulator; this artificially moves the neutral point of the line beyond it. This must be either replaced with a 3-phase ground type regulator, or a third single phase regulator installed on a neighbouring pole and a control scheme installed to ensure that all 3 phases tap in unison.

3.4.3 Longlea P131 Regulator

Longlea P131 regulator is an open delta connected regulator; this artificially moves the neutral point of the line beyond it. This must be either replaced with a 3-phase ground type regulator, or a third single phase regulator installed on a neighbouring pole and a control scheme installed to ensure that all 3 phases tap in unison.

3.5 Admittance balancing

The ground fault neutraliser uses a tuned inductance (Petersen Coil / Arc Suppression Coil) matched to the capacitance of the distribution system. The 3 phase 22kV distribution system supplied from BETS22 terminal station contains a significant amount of single phase lines. Whilst planning philosophies have always attempted to balance the single phase system, inevitably this is difficult to achieve and the objective has been load balancing rather than capacitive balancing. In order to balance the capacitance of the three phase system such that the ASC can be correctly tuned, balancing substations that utilise low voltage capacitors to inject the missing capacitance onto the system are to be placed at selected locations on the 22kV distribution system in addition to courser balancing by altering phase connections of single phase lines.

Note: Balance does not refer to the balancing of load. System balance is required from a capacitance-to-ground perspective and affected by route length and single phase connected distribution equipment.

A reconciliation (survey) of all 22kV overhead and underground lines routes shall be conducted to assess the scope of the network balancing requirements.

The following steps shall be outworked prior to GFN installation;

1. Consolidate all “Single Phase” and “unknown” conductor into the “BR”, “RW” or “WB” categories
   (i) validate “Single Phase” and “unknown” conductor where required
   (ii) spot check the validity of current phasing information
2. Consolidate all single phase transformers on the 22kV system and assign to one of the “BR”, “RW” or “WB” categories
3. Ascertain the construction types for all sections
   (i) Indicate whether LV subsidiary exists
4. Consolidate all “1 Phase” and “unknown phase” 22kV cable and assign phase information
5. If single phase circuits are used underground, ascertain the design principles behind the single phase underground sections
   (i) Conductor type, two or three core?
   (ii) Treatment of the unused core (earthed or phase bonded)—if bonded, to what phase?

The course balance shall look at sections of the system in 'switchable blocks' and for any re-phasing and finite admittance balancing opportunities in order to balance out the single phase route lengths and large single phase spurs where the capacitance is fairly easy to approximate.

A tuneable balancing approach shall then look at the system again in switchable blocks for the application of 3-phase admittance balancing substations.

The use of 3-phase admittance balancing substations will provide accurate capacitive balancing in each section. Admittance balancing substations shall be placed at the following locations to enable switching of balanced blocks of the system.

The blended approach to admittance balancing is designed to cater for the historical use of single phase spur lines, single phase cable and the variability in capacitive balancing. The number of re-phasing sites, single phase balancing units and 3 phase balancing units are also informed by experience of GSB and WND and scaled to the relative network parameter of this substation.

Table 5 Balancing requirements summary

Balancing concept	Number of sites
Re-phasing Sites	15
Single Phase Balancing Units	10
3 Phase Balancing Units	35

3.6 Automatic Circuit Reclosers (ACRs) and remotely controlled gas switches

Each RVE or VWVE ACR on the BETS network should be replaced with the current standard Schneider N27 ACR which has inbuilt voltage measurement.

Table 6 ACR replacements

Name	Operating voltage	Phase code	ACR model
SPRING GULLY P67C ACR	22kV	RWB	VWVE27

Each ACR or remote controlled gas switch requires a modern control box which has required programmable functions and up to date firmware. ACR and gas switch control box replacements are required (for CAPM5 or GCR300 control boxes) in order to:

- automatically detect REFCL operation and prevent incorrect operations de-energising customers
- provide advanced fault locating algorithms capable of detecting REFCL fault confirmation tests
- continue to operate in the traditional manner automatically when REFCL is not in operation.

Table 7 Control box replacements

Name	Control box model
Bailey p28A ACR	CAPM5
Marong South p13 ACR	CAPM5
Kangaroo Flat p70A ACR	CAPM5
Carpenter p11A ACR	CAPM5
HEATHCOTE P89A ACR	CAPM5
YACHT P1 ACR	CAPM5
STRATHFIELDSAYE 137	GCR300
BETS-AXL 194	GCR600 (CAPM3)
Eppalock Auto Sect Pole 6 CTRL	GCR600 (CAPM3)

Table 8 ACR and control box requirements summary

Units	Number of sites
ACR replacements	1
Control box replacements	9

3.7 Fuse savers

HV Fuses pose a difficulty in operating a network with a REFCL. Maintaining capacitive balance is critical in the network, and scenarios that result in 1 or 2 out of 3 fuses blowing in a 3 phase section, such as phase-phase faults can result in large capacitive imbalances. These imbalances can result in loss of REFCL sensitivity, REFCL maloperations resulting in widespread outages or REFCL backup schemes operating to remove the REFCL from service.

Fuse Savers are to be installed as a 3 phase ganged unit such that when any individual phase operates for a fault, all 3 phases open in unison de-energising a balanced section of the network regardless of the fault type.

Fuse Savers are required to operate for any fused section with a downstream network capacitive charging current of 540 mA or greater.

In some locations where the network fault levels are high, Fuse Savers cannot be used as they do not have the appropriate fault breaking capacity. In these situations, an ACR is required to clear faults as a three phase device else the feeder will be tripped on days of high sensitivity.

Table 9 Fuse saver requirements

Units	Number of sites
Fuse savers	20
ACRs	0

3.8 HV underground cable

Experience from REFCL testing has shown that a percentage of HV underground cable is likely to experience failure due to elevated phase to earth voltages experienced in a resonant network. An allowance for cable failure is to be made for the transition to resonant earthing.

Table 10 HV underground cable requirements

Location	Length (m)
Cable failure length	3,214

3.9 Distribution switchgear

Overhead distribution switchgear has been shown to be largely resilient to the phase to earth over-voltages experienced in a resonant network. There is no planned replacement of these assets.

Resilience testing has shown that Felten and Guilleaume ground mounted kiosk switchgear is not capable of withstanding 24.2kV phase to earth voltages. The inherent design and construction of these units preclude them from any repair works and as such must be replaced.

Table 11 Felten and Guilleaume switchgear replacements

Location	Kiosk Size (kVA)
BEELZEBUB NEW MOON PLANT	1000
KAWANA HASTINGS KIOSK	315
LYTTLETON-WILLIAMSON	1500
MARCUS - MONSANTS	315

Location	Kiosk Size (kVA)
MC IVOR-LORDS RACEWAY	1000

3.10 HV customer isolation substations

The Electricity Distribution Code stipulates that at the point of connection to a customer on the 22kV network, the phase to earth voltage must be no greater than 80 per cent for up to 10 seconds.

In order to maintain compliance with the code, the installation of HV isolation substations is required.

The service provider is to ensure that the detailed design of these installations considers:

- a delta zig-zag (Dzn0) vector group transformer is required to provide the isolation
- isolation substation to be sized appropriate for the total size of the customer's load, taking into account any generation
- voltage control requirements for the customer is likely to require tap changing capability for larger customers
- station service supply via the tertiary winding to provide supply to protection, metering and control circuitry
- appropriate HV source side protection to protect for faults in the substation transformer
- appropriate HV load side protection to protect for faults between the substation and customer protective devices
- note that customer protection is in some cases not at the point of connection and there is a risk of sensitive earth faults
- bunding and other environmental considerations for substations
- undergrounding of any electrical conductor between the isolation substation and customer connection

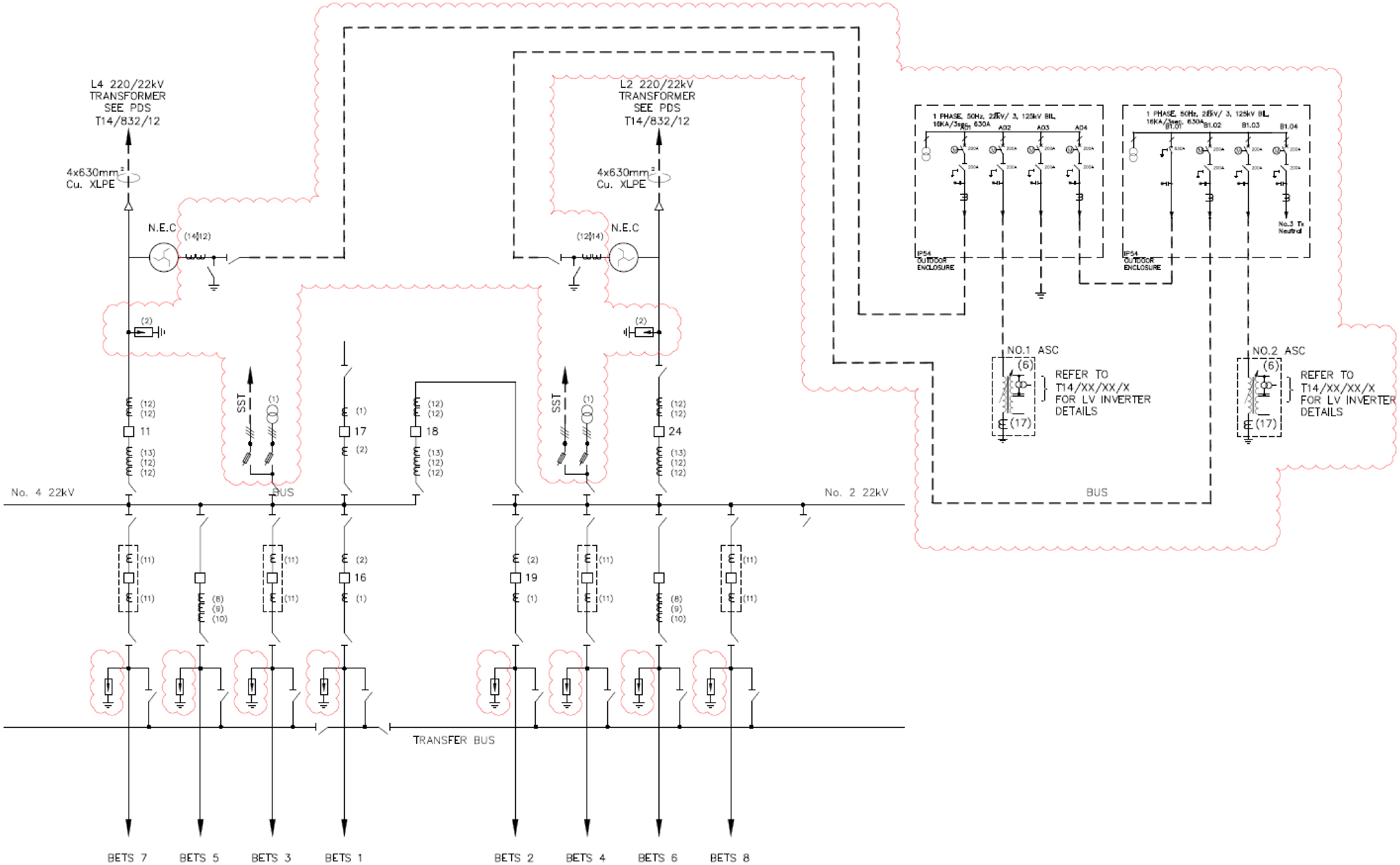
HV customer connection sizes are set out in table 12.

Table 12 Isolation substation requirements

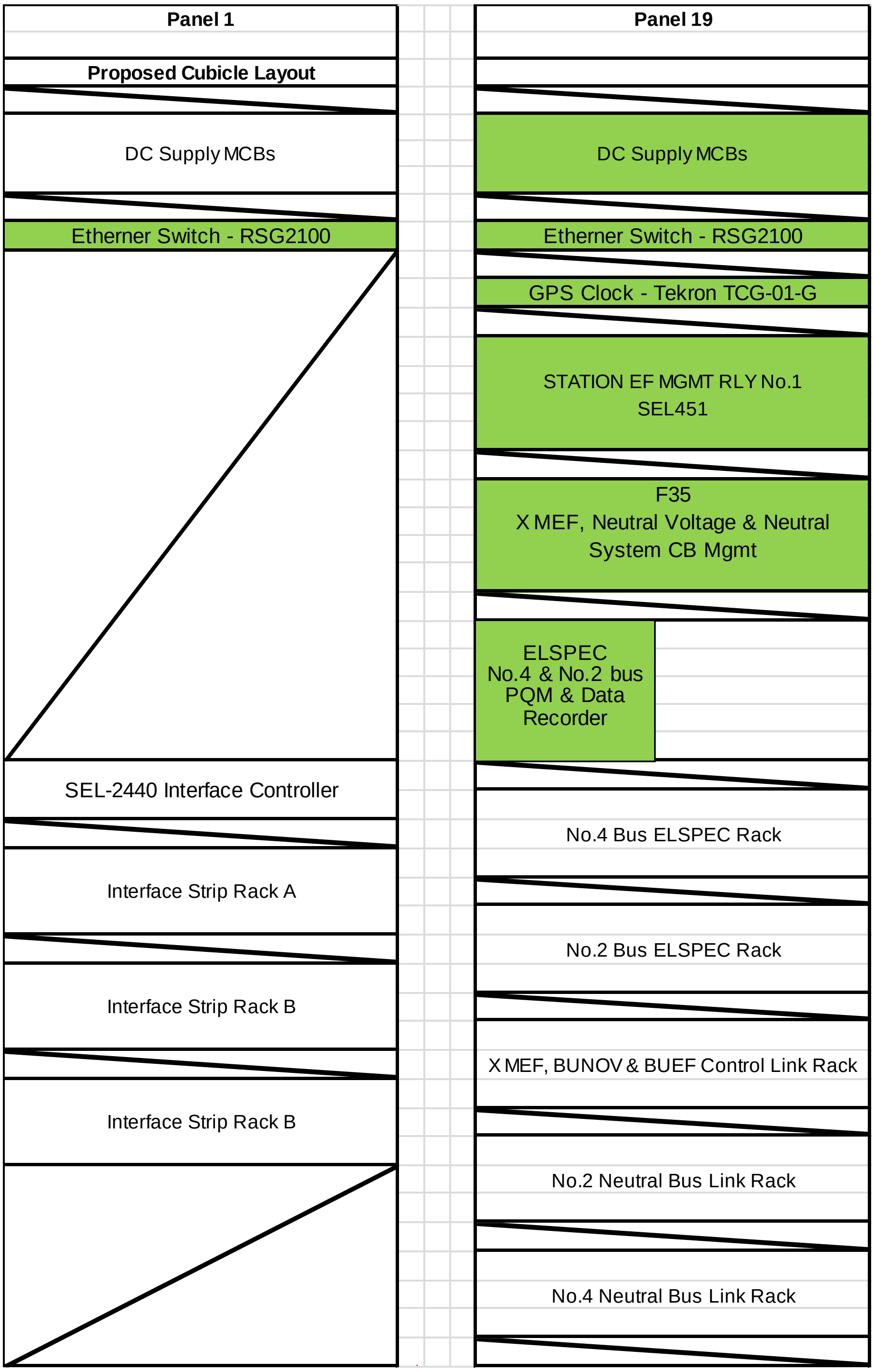
Size	Quantity
3 MVA	2
6 MVA	2

4 Appendix

4.1 Proposed Plant Data Sheet



4.2 Cubicle Layout



4.3 Ethernet Connectivity